Subselective preoperative embolization for meningiomas

A radiological and pathological assessment


Institute of Neurological Sciences, Southern General Hospital, Glasgow, Scotland

Over a 2-year period the authors have studied the effects of preoperative subselective embolization of meningiomas. Thirty-six consecutive patients shown by computerized tomography (CT) to have a meningioma underwent selective internal and external carotid artery angiography, and any significant external carotid artery feeders were embolized (27 cases). It was found that CT and dynamic radioisotope scan findings were unable to predict the degree of vascularity of the tumor or its suitability for embolization. Furthermore, these tests, repeated after embolization, were unreliable in detecting either the extent of necrosis or reduction in blood flow. The effects of embolization upon surgery were recorded, and the excised tumor specimen examined for evidence of thrombosis and infarction. Subselective embolization was determined to be a simple, safe, and effective method of producing tumor necrosis and intraoperative hemostasis in selected patients.

KEY WORDS • meningioma • computerized tomography • angiography • embolization • pathology • tumor necrosis

THE use of preoperative embolization of certain meningiomas has been advocated because it can produce tumor necrosis and relatively avascular operative conditions.1-3 These combine to facilitate surgical removal and so reduce the risks to the patient. The reports recommend the use of superselective catheterization and injection of Gelfoam or liquid embolic material, either with or without balloon occlusion of the proximal vessels. The complexity of this technique makes it time-consuming, and success cannot always be achieved even by the most skilled operator.

Subselective angiography and embolization for meningioma is much simpler to perform and relatively safe if emboli not less than 0.5 x 0.5 mm are used. We have used this technique to determine if satisfactory results can be achieved. Evaluation of the efficacy of such embolization was made by angiography, computerized tomography (CT), radioisotope scanning, histopathology, and surgical assessment of the operative conditions. Some surgeons operate on most meningiomas on the basis of the CT information alone, the small risk of angiography being considered to outweigh any additional information that might be obtained. We have, therefore, studied the results of noninvasive investigations (CT and radioisotope scanning) to ascertain if they could be used to indicate the patients in whom angiography and embolization would be appropriate.

Clinical Material and Methods

Radiographic Assessment

Over a 2-year period, 36 patients were examined. There were 19 men and 17 women, with an average age of 60 years (range 25 to 82 years). All CT scans were performed on an EMI 1010 head scanner and each patient was given 50 ml of Urografin 310M for contrast enhancement. On the basis of the CT scan, the location of the tumor, its density, the extent of associated edema, and the degree of enhancement were estimated. All patients were started on oral dexamethasone after the CT scan and before angiography.

Dynamic radioisotope brain scans were performed on a gamma camera in the frontal projection with the patient sitting. A bolus of 500 MBq technetium-99m-labeled sodium pertechnetate was injected rapidly into the antecubital vein, followed by a 10-ml flush of saline. Data were then collected on a computer in 0.5-second frames for 50 seconds after the injection. Using the computer light pen, two areas of interest were drawn on the resulting composite image, one encompassed the
Preoperative embolization of meningiomas

tumor, the other a mirror image area in the contralateral normal hemisphere. Curves of activity against time were produced for each of these regions. An index of the relative flow to the tumor compared to the normal tissue was obtained by taking the ratio of the integrated upslopes of the curves, as shown in Fig. 1.

Static radioisotope brain scans were performed 5 minutes after the dynamic scans. Using the most appropriate view for each tumor, regions of interest were again selected for the tumor and for an area of normal tissue. Since the radioisotope was still, at this time, mainly confined to the vascular compartment, the ratio of counts in the regions was used as a measure of the relative blood volume of the tumor.

Both of the above radioisotope measurements are semi-quantitative. The apparent activity seen in a tumor includes activity in the superficial tissues and in the normal brain surrounding the tumor. As a result, changes in the blood volume of the tumor will be underestimated by this method; a proper quantitative assessment would require a tomographic technique.

Each patient underwent selective internal and external carotid angiography with bilateral examination if indicated. A subjective assessment was made of the proportion of tumor vasculature supplied by the internal and external systems, and we also assessed the "vasularity" of the tumor, based upon the size of the arterial feeders, the degree of blush within the tumor, and the presence of any early draining veins.

Embolization

Embolization was performed at the time of the diagnostic angiogram. We used either Lyo-dura or Gelfoam particles (measuring 0.5 x 0.5 mm to 1 x 1 mm) in saline, since we also wished to find out whether nonabsorbable or absorbable emboli were more effective in the short term. During the injection of the emboli, the tip of the catheter was placed in the terminal external carotid artery just proximal to the origin of the maxillary branch. The emboli were injected slowly so that the higher blood flow through the feeding vessels would carry the particles into the tumor. Test contrast injections were made from time to time and the embolization stopped when neither tumor nor feeding vessels could be seen, or when altered hemodynamics would have allowed differential flow rates to carry emboli into normal tissue. In eight patients in whom the superficial temporal artery was large and not supplying the tumor, the artery was occluded by finger compression during embolization to avoid accidental occlusion.

From the immediate postembolization external carotid angiogram, we determined if there had been occlusion of the tumor circulation and also studied the extent of occlusion of the feeding vessels (Fig. 2). Our aim was to occlude vessels within the tumor and not just the large feeding vessels. This was done in the hope of producing tumor necrosis as well as intraoperative hemostasis.

![activity curves](image)

**FIG. 1.** Typical activity/time curves for a meningioma and normal tissue. The relative flow index (I) is obtained from the ratio I = T/N, where T is the area under the upslope from the appearance time, t₀, until two-thirds of the peak value, t₂/₃, and N is the corresponding area for the normal tissue for the same time interval.

The internal carotid angiogram was performed before embolization but not repeated afterward. This was to avoid the possibility of accidental embolization by particles lying undetected within the catheter. Radioisotope and CT examinations were repeated between 2 and 6 days after embolization in as many cases as was feasible. Operations were carried out on average 5 days after embolization (range 2 to 21 days). The operative notes were reviewed for comments as to the vascularity or ease of excision of the tumor.

**Summary of Cases**

Of the 36 patients who underwent angiography, tumor embolization was carried out in 27, and 26 of these tumors were removed. After the embolization procedure, the relatives of one demented patient withdrew consent for operation. Nine tumors did not have significant external carotid feeders and therefore were not embolized.

**Angiographic Appearance**

Of the 36 patients, five had tumors supplied only from the internal carotid system, one of which had a grossly enlarged middle meningeal feeding vessel arising from the ophthalmic artery. In two further patients there was no detectable blood supply to the tumor. In the remaining 29 patients, 13 tumors had an external carotid supply only while 16 had a combination of both internal and external feeders. Ten patients were considered to have very vascular meningiomas, 13 moderately vascular, 11 slightly vascular, and two avascular. To simplify the presentation and analysis of results, we have considered the moderately and very vascular tumors to be "vascular" and the slightly vascular and
avascular tumors to be "hypovascular." The relationship of tumor site to vascularity is shown in Table 1.

Computerized Tomography

The relationship between the angiographic vascularity and the CT scan findings is shown in Table 2. Mixed-density tumors (tumors containing low-density areas) tended to be more vascular, and there was a trend for those with marked enhancement and marked edema to be more vascular. Nevertheless, similar appearances could be found in many of the hypovascular group. We did not find a specific CT appearance that could predict that the tumor was supplied solely from the external carotid artery.

Radioisotope Imaging

There was no correlation between the angiographic grading of vascularity and the radioisotope assessment of blood flow or blood volume (Table 3). We grouped the tumors according to whether the flows and volumes were greater or less than an arbitrary value of twice that of the normal control area.

Embolization

Of the 27 meningiomas embolized, 14 were embolized with Gelfoam and 12 with Lyo-dura. One patient developed severe spasm and accidental embolization of the middle meningeal vessel during angiography so that we did not inject artificial material (later, infarction was found within this tumor). There were no immediate complications of angiography or embolization. In fact, improvement was noted within the following 24 hours in two patients: one patient with dementia and one with proptosis. In no case was there any evidence of postembolization cranial nerve palsy. Postoperatively, a small (2 x 2 cm) area of scalp necrosis requiring plastic surgery developed in one patient.

The final postembolization follow-up angiogram showed complete absence of the tumor circulation in 23 cases, and 80% to 90% occlusion in the remaining four. On the other hand, because repeat internal injection was thought to be inadvisable (in case of inadvertent delivery of any emboli remaining in the catheter), it is not known if this supply had increased after occlusion of the external supply. In 15 patients, the middle meningeal vessel was occluded above the skull base and in 10 below the skull base (two patients had no meningeal feeding vessels).

We found the Lyo-dura easier to cut into small pieces and to inject but, as judged by the angiographic criteria, the two materials were equally effective.
Preoperative embolization of meningiomas

### TABLE 2

<table>
<thead>
<tr>
<th>CT Scan Characteristics</th>
<th>Vascular Group</th>
<th>Hypovascular Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>isodense</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>hyperdense</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>mixed density</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>edema</td>
<td></td>
<td></td>
</tr>
<tr>
<td>none to slight</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>moderate or marked</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>enhancement grading</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>3-4</td>
<td>19</td>
<td>12</td>
</tr>
</tbody>
</table>

*For definition of groups see text.

### TABLE 3

<table>
<thead>
<tr>
<th>Assessment of Tumor Supply</th>
<th>Vascular Group</th>
<th>Hypovascular Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>blood flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; twice control value</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>&lt; twice control value</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>blood volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; twice control value</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>&lt; twice control value</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

*For definition of groups see text.

**Postembolization CT and Radioisotope Scans**

Computerized tomography was performed after embolization in 17 patients who subsequently underwent surgery. The appearance of new low-density areas within the tumor was accepted as evidence of necrosis. These areas were found in eight patients. In the remaining nine, there was no change in either the density of the tumor or in its pattern of enhancement. Of the eight patients who developed necrosis, seven had only external carotid feeders; of the nine without change, three patients also had external carotid feeders only but four had major internal carotid supply. Only 10 patients had postembolization radioisotope studies performed. In four patients a reduction in blood flow was noted, in three we did not see a change, and in three flow had apparently increased. Similarly, the relative blood volume measurements showed a reduction in five cases, no change in one, and an increase in three. In nine of the 10 cases, the pattern of uptake seen on the static scans did not change to any significant extent.

**Operative Findings**

Of the 27 patients whose tumor was embolized, 26 underwent an operation. No comments were made as to the vascularity of the tumors in six cases. The surgeons considered that the embolization had facilitated surgery in 13 patients, that the tumor was not affected in three, and that the tumor bled profusely despite the embolization in four. Of the 13 patients in whom embolization was considered beneficial, nine had purely external carotid feeders, whereas of those with persistent bleeding or no appreciable improvement, only one had an entirely external supply. Despite the apparent lack of benefit, this tumor had shown evidence of necrosis on the repeat CT scan.

**Pathological Examination**

Surgical specimens were received from each of the 26 patients operated on. Only three tumors were received intact, of which one showed a central area of infarction on gross examination. The remaining 23 tumors had been debunked either by curettage or suction, and the specimens consisted of multiple small fragments.

The specimens were fixed in 10% formal saline, and representative blocks were selected randomly for histological examination. The meningiomas were typed histologically according to the categories in the World Health Organization classification of central nervous system tumors. Twenty cases were "transitional," three were "syncytial," two were "angiomatic," and one was "hemangiopericytic" in type. None of the tumors showed features of malignancy, although three cases, including the hemangiopericytic tumor, showed cerebral invasion locally.

The sections were examined for microscopic evidence of infarction within the tumor and the presence of embolic material and thrombosis in the tumor or associated dura. In 10 cases, embolic material was identified within arterial vessels: in seven within the dura, in two within the tumor itself, and in one within both dura and tumor. Embolic material was intimately associated with thrombosis in seven cases, and associated with thrombosis in separate vessels in three cases.

Infarction was defined as a circumscribed area showing pallor of staining and nuclear disintegration, with or without an inflammatory response, and large enough to be seen with the naked eye in the stained section. Pallor of staining on its own was not taken as evidence of infarction. By these criteria, infarction was found in 14 cases, with an area ranging upward in size from a minimum diameter of 0.2 cm. Infarction was associated with embolic material or thrombosis in seven cases. Five specimens that showed scattered microscopic foci of necrosis have been excluded from the definition of infarction, as similar appearances may be seen in nonembolized meningiomas as a feature intrinsic to the tumor. If these five cases showing microscopic evidence of embolization without infarction are added to the 14 cases with infarction, and a further patient whose tumor showed vascular thrombosis without infarction is included, then 20 of the 26 cases are consistent with a technically successful embolization.

There were discrepancies between the CT scan and
pathological evidence of infarction. In six of the 17 cases, infarction was detected both microscopically and in the repeat CT scan. In four cases infarction was found on microscopic examination, but was not evident on the CT scan, and in two there was CT scan evidence of infarction which was not seen microscopically. In the remaining five cases, neither CT nor histological evidence of infarction was found, although emboli were found in two of these specimens.

Discussion

Our findings show that a simple subselective technique for angiography and embolization can produce effective hemostasis and tumor necrosis in selected patients with meningioma. This is because the majority of meningiomas are supplied wholly or in part by the external carotid system, and even though many have multiple external feeders these can all be effectively embolized by subselective flow-directed embolization with either permanent or nonpermanent embolic particles. The immediate postembolization angiogram showed that subselective embolization produced total occlusion of the feeding vessels and tumor circulation in 85% of patients, and 80% to 90% obliteration in the remainder.

Although the most effective hemostasis was achieved in meningiomas that had only external carotid supply, significant tumor necrosis was found even in the presence of large internal carotid artery feeders. The frequency of significant internal carotid supply to the meningioma was notable. The supply was not restricted to the tumor capsule and involved convexity as well as basal meningiomas. This is contrary to the observations made by Djindjian and Merland.

Objective evidence of improved operative conditions was difficult to obtain. Several surgeons of differing experience were involved in the series, and the opinions expressed were naturally subjective. Nevertheless, in several patients, experienced surgeons noted a remarkable lack of bleeding and also that the tumor was unusually soft and easy to remove from vital structures. Marked hemorrhage occurred only in four patients, and each of these had significant internal carotid feeding vessels equivalent to between 20% and 50% of their total blood supply. Nevertheless, each of the four had shown pathological evidence of effective embolization. It is possible, as Djindjian and Merland have shown, that where there is an appreciable internal carotid supply, this may increase after occlusion of the external carotid feeders. If so, embolization may be of limited benefit and even contraindicated in such patients, as bleeding from internal carotid vessels could be more difficult for the surgeon to control than external carotid artery bleeding. Further information is needed about this point.

It was not the primary aim of this study to determine if preoperative embolization improves ultimate outcome. This would be a complex task and would need to take account of the variations in patient's age, neurological state, and tumor size, site, and vascular supply. However, it may be relevant that among the patients in this study not only were there no operative deaths, but no patient incurred a postoperative neurological deficit.

Pathological criteria for iatrogenic infarction were strict, and required a large circumscribed area of pallor with associated nuclear disintegration. Small foci of necrosis are not uncommon in meningiomas and were excluded from our definition of iatrogenic infarction. The histological studies commonly showed tumor necrosis, and even that there were emboli within the small vessels of the tumor. This finding is in contrast to Berenstein and Russell's report that perivascular necrosis occurred only in patients in whom they used liquid or powder emboli and not in those in whom Gelfoam particles were used. Although they considered that particulate Gelfoam did not enter the circulation within the tumor itself, they did not state the size of the Gelfoam particles or the nature of the tumors they examined pathologically. It may be that we used smaller embolic particles or that different tumors respond in different ways. The criteria used to assess the pathological findings may also be dissimilar.

Sampling errors may account for some of the specimens showing emboli but not infarction. Indeed, in two patients whose CT scan had shown necrosis there was no histological evidence of necrosis. These tumors had been debulked at operation and only the tissue at the periphery of the tumor was sent for histological examination. In no patient was there necrosis of the whole tumor: a rim of viable tissue was always present (Fig. 3). Therefore, embolization by itself seems rarely, if ever, a method of curing meningioma. On the other hand, it may be considered as a method of achieving palliative shrinkage in debilitated patients or in those deemed unfit for surgery for other reasons.

Our efforts to find a noninvasive method to select patients suitable for embolization, or to demonstrate its
Preoperative embolization of meningiomas

effect, were unrewarded. Radioisotope and CT scans were of little value in predicting the vascularity of a meningioma or its potential for embolization. Only carotid angiography provided the necessary information. While intra-arterial angiography carries a small though significant hazard, the wider use of digital subtraction venous angiography may provide a less invasive method of selecting tumors suitable for embolization. Radioisotope and CT studies were less sensitive indicators of infarction than histological examination. The CT scan failed to detect necrosis in many patients whose tumor was proven histologically to show necrosis. This may have been because there was persisting tumor perfusion from feeding vessels from the internal carotid artery, because of revascularization of the external carotid feeders, or because the areas of necrosis were too small for the resolution of the CT scanner.

Similar results were found with the radioisotope studies. Overall, no gross changes were seen in the group of patients who had postembolization scans, in terms of either flow, volume, or general pattern of uptake. However, the three patients who had purely external carotid feeders did show some reduction, but not ablation, of blood flow and volume. On the other hand, in some of the patients in whom there were both internal and external feeders, the blood flow and volume actually increased. This would tend to substantiate the view that internal feeders can increase after obliteration of external feeders.5 It is interesting to note that an increase in flow, assessed by dynamic brain scans, has been previously reported in embolic brain infarction.4

We agree with Merland, et al.,3 that any large convexity or sphenoid wing meningioma may benefit from embolization, and it is particularly helpful in patients who are high anesthetic risks or whose meningioma has invaded bone and soft tissue. Our demonstration that a relatively simple technique of angiography and embolization can be effective in carefully selected patients may encourage others to apply this technique.

References


---

Manuscript received June 20, 1983.

Address reprint requests to: Evelyn Teasdale, M.R.C.P., F.R.C.R., Institute of Neurological Sciences, Southern General Hospital, Govan Road, Glasgow G51 4TF, Scotland.